

## Implications of Extended Solar Minima

Authors:

M. Adams, J.M. Davis

Since the discovery of periodicity in the solar cycle, the historical record of sunspot number has been carefully examined, attempting to make predictions about the next cycle. Much emphasis has been on predicting the maximum amplitude and length of the next cycle. Because current space-based and suborbital instruments are designed to study active phenomena, there is considerable interest in estimating the length and depth of the current minimum. We have developed criteria for the definition of a minimum and applied it to the historical sunspot record starting in 1749. In doing so, we find that 1) the current minimum is not yet unusually long and 2) there is no obvious way of predicting when, using our definition, the current minimum may end. However, by grouping the data into 22-year cycles there is an interesting pattern of extended minima that recurs every fourth or fifth 22-year cycle. A preliminary comparison of this pattern with other records, suggests the possibility of a correlation between extended minima and lower levels of solar irradiance.

# Implications of Extended Solar Minima

M. Adams, J.M. Davis, Allyn F. Tennant

NASA/Marshall Space Flight Center, Huntsville, AL 35805

**Abstract:** Since the discovery of periodicity in the solar cycle, the historical record of sunspot number has been carefully examined, attempting to make predictions about the next cycle. Much emphasis has been on predicting the maximum amplitude and length of the next cycle. Because current space-based and suborbital instruments are designed to study active phenomena, there is considerable interest in estimating the length and depth of the current minimum. We have developed criteria for the definition of a minimum and applied it to the historical sunspot record starting in 1749. The beginning of the minimum occurs (for monthly averaged sunspot number) with the first month following two consecutive months of fewer than eleven sunspots. If the monthly averages are smoothed, we use a threshold of fifteen months, in order to include all minima of the modern sunspot record. In doing so, we find that 1) the current minimum is not yet unusually long and 2) there is no statistically significant way of predicting when, using our definition, the current minimum may end. However, we note a possible hundred year cycle and using our definition of minimum start, we predict that the current minimum will end in either August 2009 or May 2010. A preliminary comparison of this pattern with other records, suggests the possibility of a correlation between extended minima and lower levels of solar irradiance.

## Background and Motivation

The SUMI sounding rocket will attempt the first measurements of the Sun's magnetic field above the chromosphere. Because it is a first measurement, we have wanted to observe a solar feature with magnetic characteristics extending into the transition region that will provide a strong enough signal for us to measure.

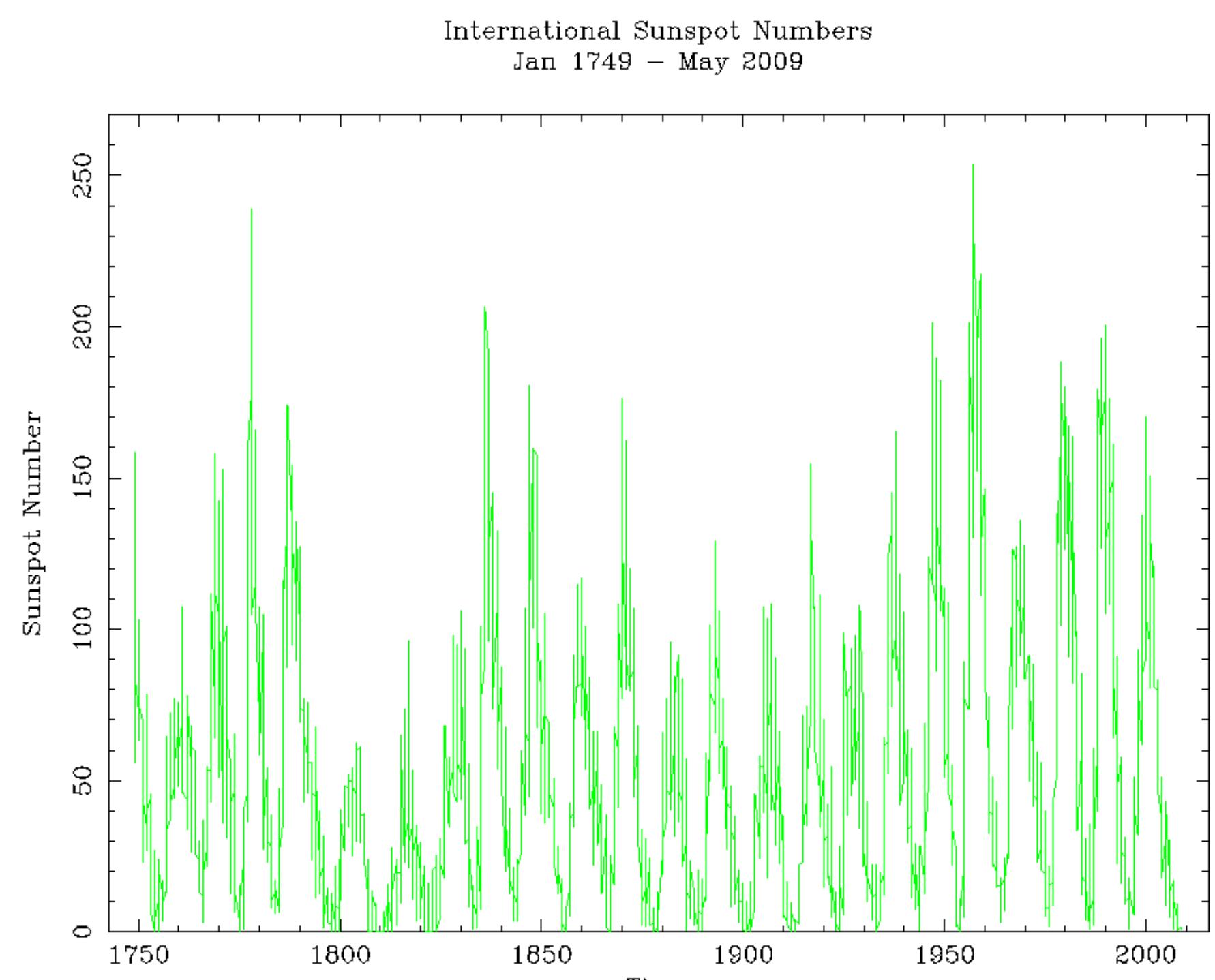
### We need a sunspot!

Based on recent cycles and predictions, cycle 23 was expected to transition into cycle 24 no later than mid 2008,  $\pm 6$  months.

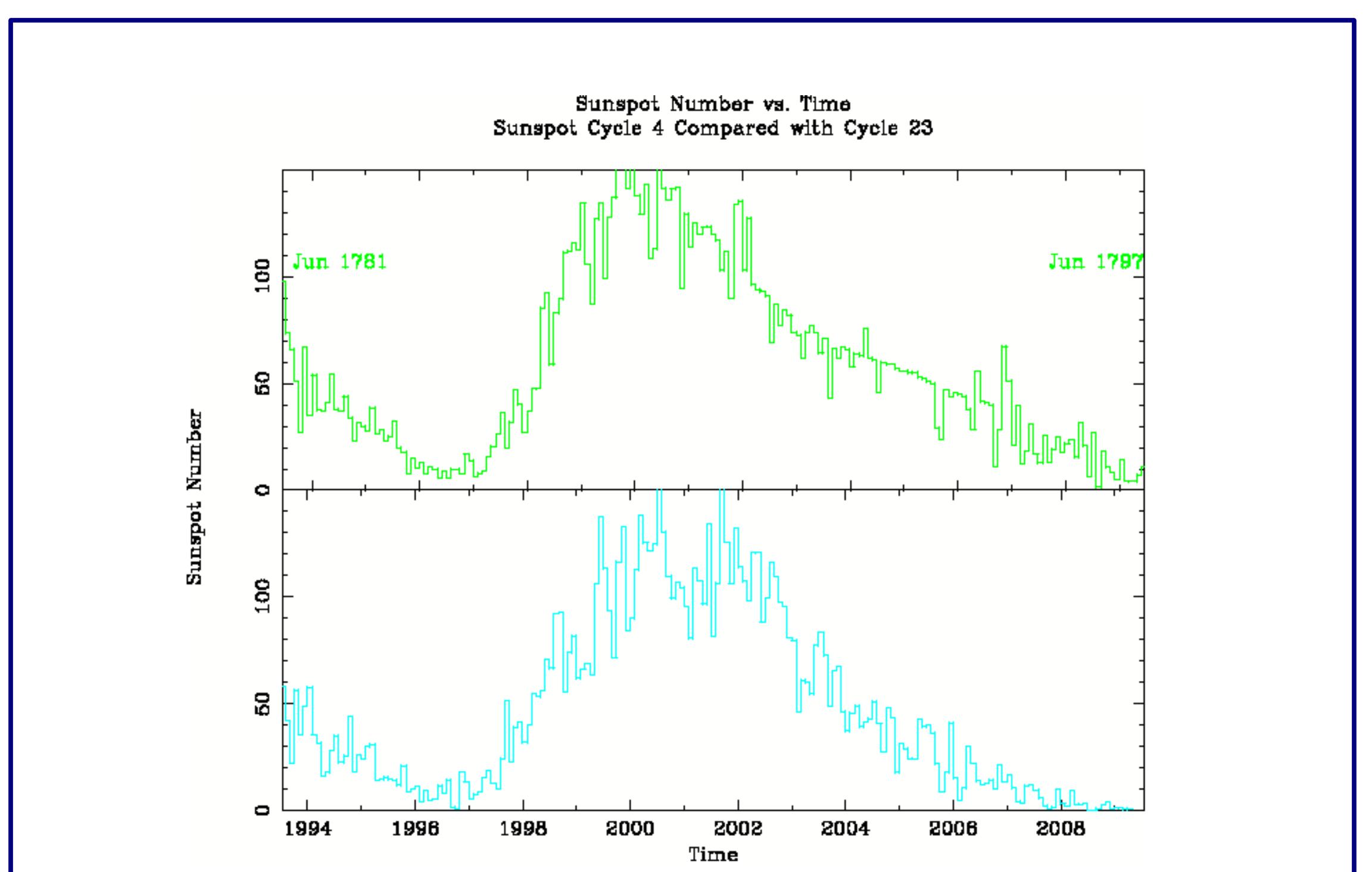
In the space-age, much attention has been paid to predicting solar maxima, with little attention to minima. We have seen little expectation that a minimum might be extended.

### Definition of Minima

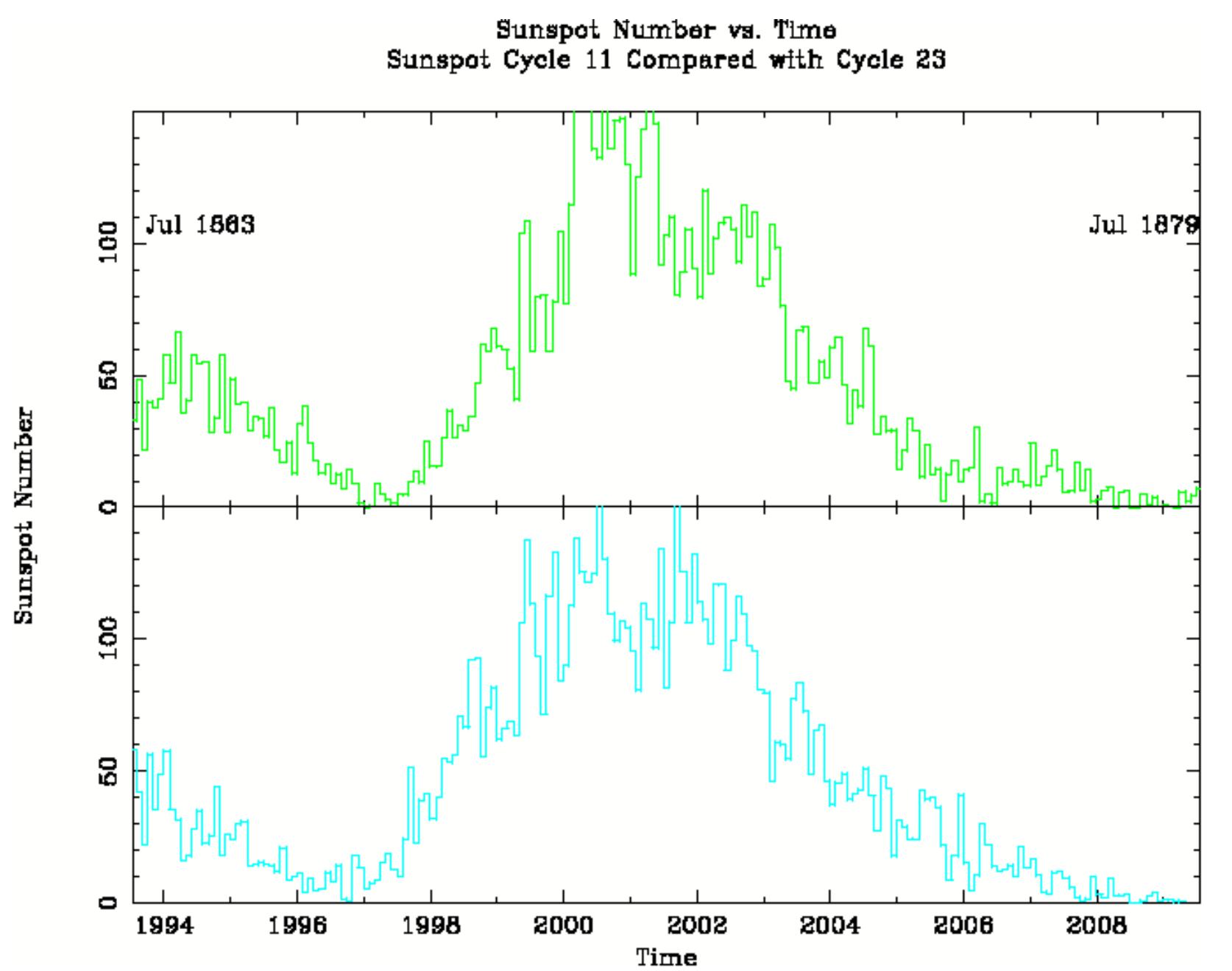
Based on examination of the sunspot cycle back to 1749, we define minimum to begin when the international monthly averaged sunspot number falls to below eleven for at least two consecutive months. The beginning of minimum is the first month of that occurrence. The end is defined to be the last occurrence of fewer than eleven spots of the minimum under consideration. Eleven was selected as reasonable and to compensate for the way sunspots are counted ((num grps x 10) + num spots). Using smoothed numbers, our threshold changes to fifteen to include all the minima of the sunspot record.



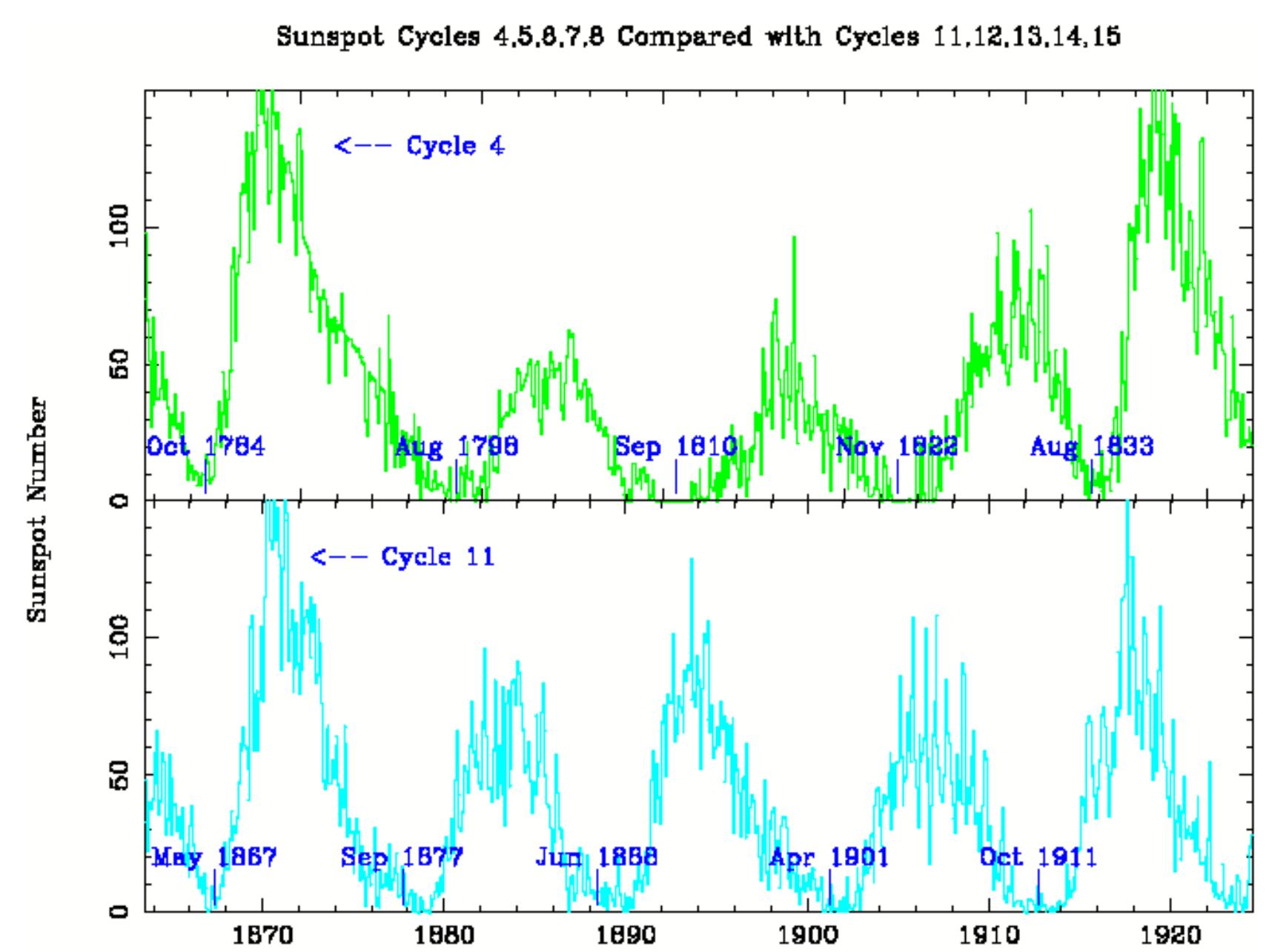
Note the small cycles around 1800 and 1900. The plots in the middle panel of this poster show details and compare with the current cycle.



Cycle 4 is compared with cycle 23. Note similar shapes and slope of the decline to minimum. However, we must point out that data in cycle 4 were interpolated.

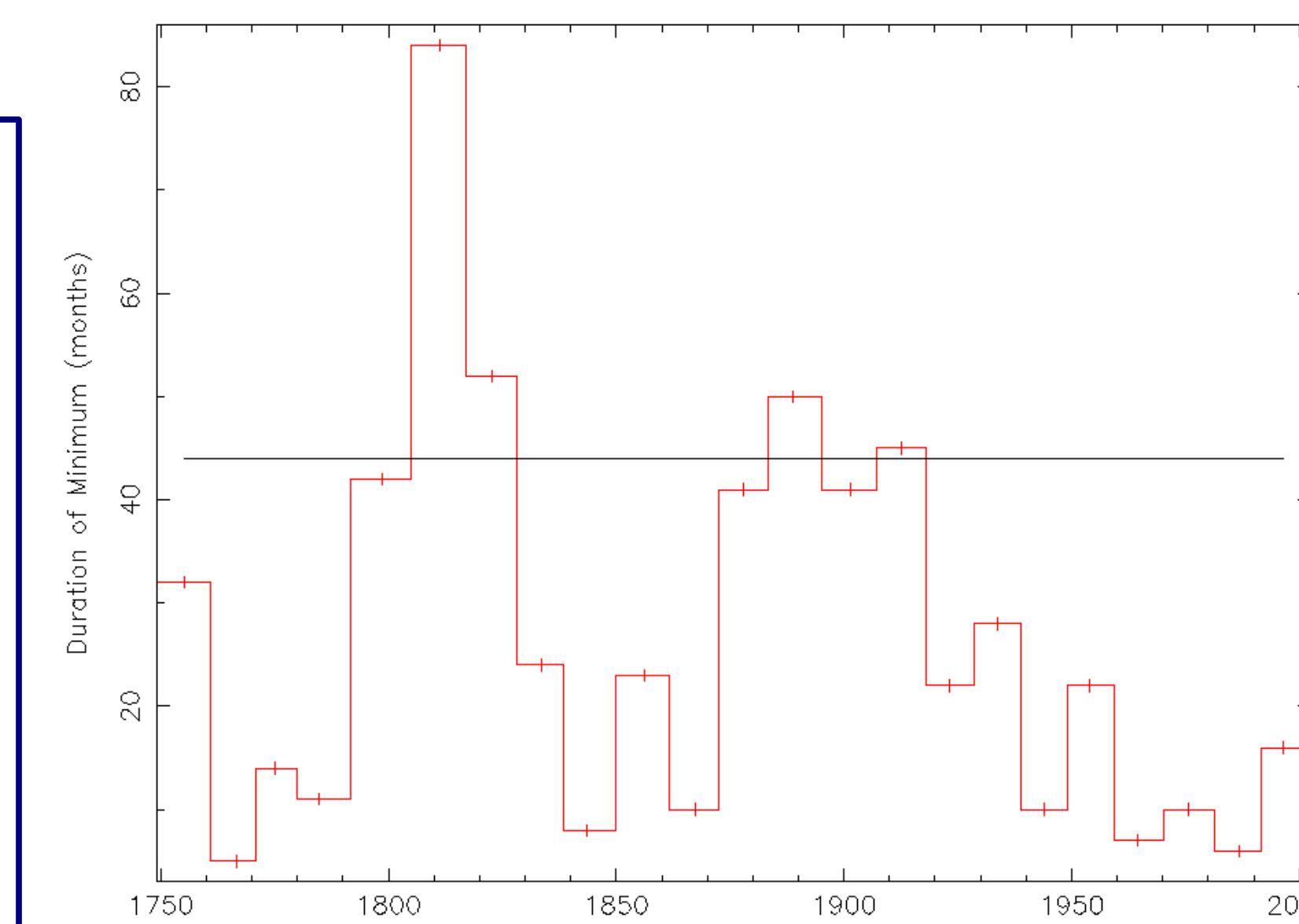


Cycle 11 is compared with cycle 23. Note again, the similar shape and slope of the curve.



Details of several cycles following cycles 4 and 11 with approximate midpoints of minima marked.

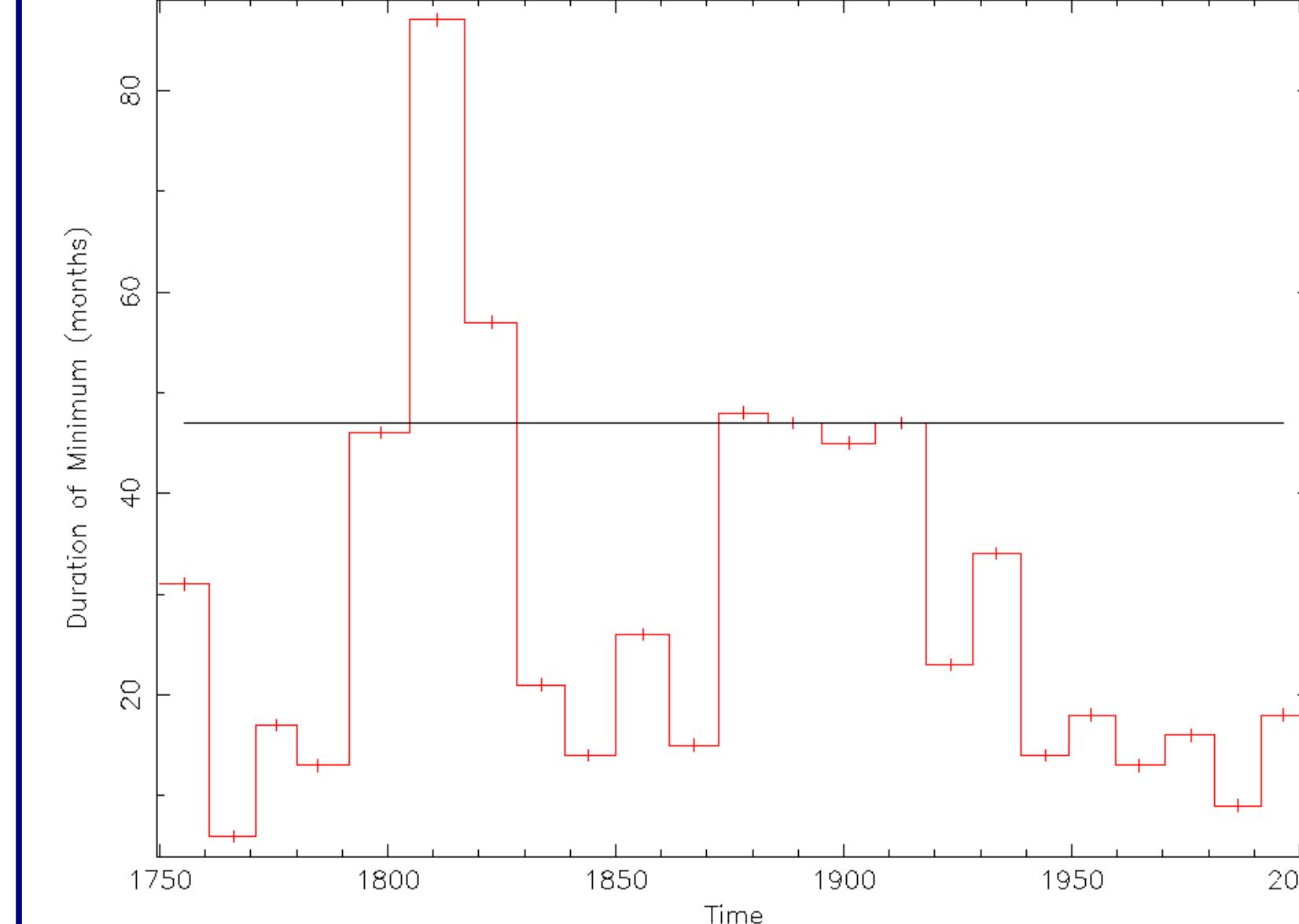
Duration of Minima from Monthly Averaged Sunspot Numbers  
Minimum Threshold = Eleven



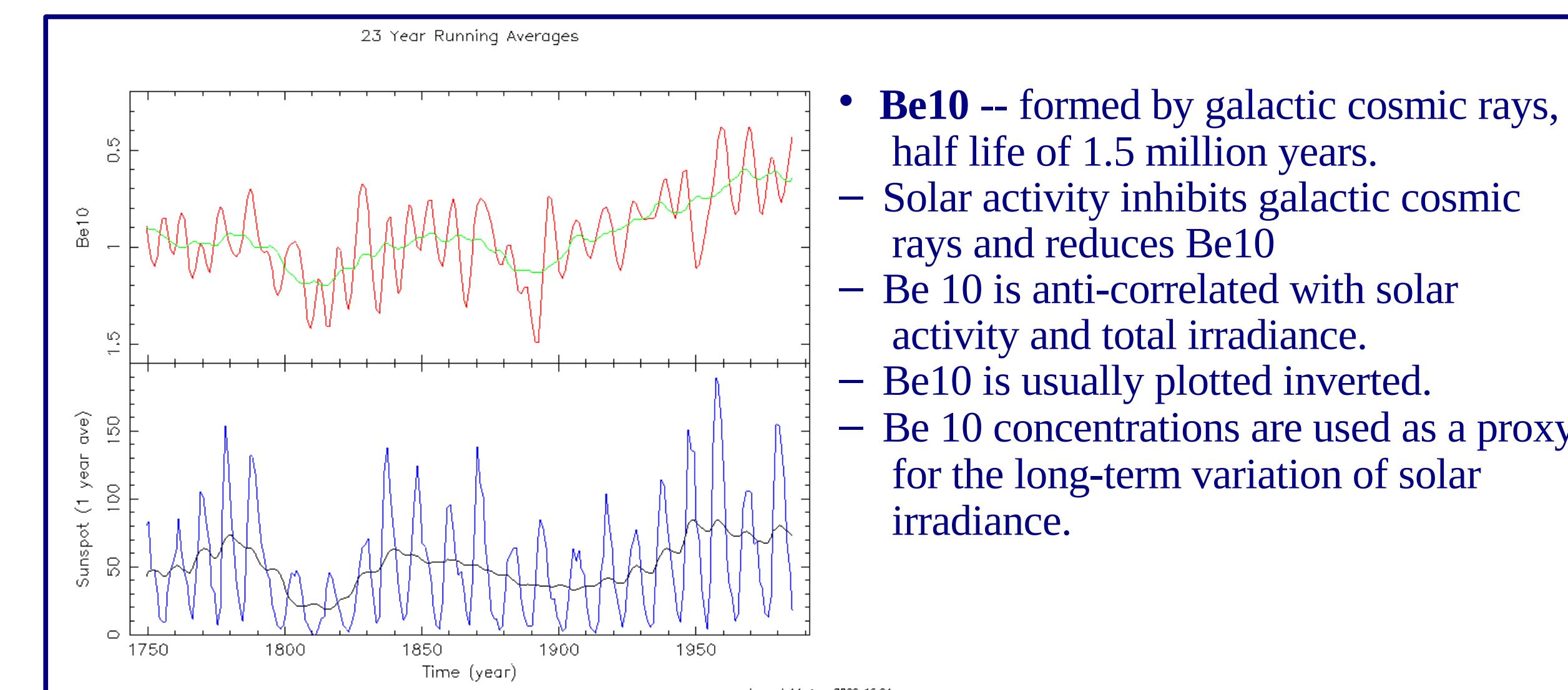
**Duration from Monthly Averages:** The figure plots the number of months of each minimum vs. time. Note the grouping that is around 47 months.

Current Minimum	
Raw	
Smooth	
Begin	2006.1
2006.6	
Duration (yrs)	3.7 3.9
End	2009.8 2010.5

Duration of Minima from Smoothed (13 Mon Running Avg) Sunspot Numbers  
Minimum Threshold = Fifteen



**Duration from Smoothed Numbers:** When sunspot numbers are smoothed, two minima (1970s and mid 1980s) disappear when our definition of duration is applied, which requires a different threshold. Fifteen is the smallest value that still allows all cycle minima to be distinguished. Duration of minimum increased by about two months.



## Results and Discussion

A motivation for this project was to examine the sunspot record for clues that might answer this question, "when will this minimum end?" We realize that the sunspot record itself is simply too short to answer this question with any degree of statistical certainty. However, we find the hint of a 100 year cycle in the Be10 data, intriguing. Coupled with the current extended minimum and using our definition of when a minimum actually begins, we predict that the sunspot number will rise above eleven for at least two months around August, 2009 or using the smoothed numbers, it will rise above fifteen in May, 2010. Unfortunately, the Be10 data we acquired were smoothed with a 6-year filter and are not useful for measuring the duration of minima, which typically last less than two years. Future work with the raw values may provide some insight into these "extended minima". We speculate that if the current minimum continues, we will see a solar-induced cooling in global temperatures.